White Oak, Silver Spring, Maryland

NAVAL ORDNANCE LABORATORY MEMORANDUM 10619

2 December 1949

From: L. LoFiego and E. H. Winger

To: NOL Files

Subj: Spectrographic Studies of Pyrotechnic Flares (NOL-40-Re2a-400-3)

Abst: The laboratory was requested to develop a pyrotechnic composition which during burning would emit radiations which are not present in solar radiations at an altitude of 60,000 feet. Atmospheric ozone at altitudes above 60,000 feet absorbs radiations of less than 2900 A. It would be impractical to consider wavelengths of less than 2700 A because of atmospheric scattering. For these reasons, attempts were made to develop compositions which would provide radiant energy in the 2700-2900 A wavelength region. Several compositions were prepared and spectrographically examined for ultra violet content. Although incandescent particles in the pyrotechnic flames of several compositions produced radiation continuums which extended to the desired spectrum region, the total available energy in this region was found to be exceedingly small. Attempts to increase the radiant energy in the 2700-2900 A wavelength region by excitation of molecular band spectra were not successful.

Fwd: This memorandum is based on experimental work carried out jointly by representatives of the Ammunition and Physical Optics Divisions. The data and conclusions represent the best judgment of these divisions at this time.

Refs: (a) BuOrd ltr. to NOL File NP51(Re2a) dated 29 June 1948, NOL File NP51/S78-1(6-152)

(b) Pearse, R.W.B. and Gaydon, A.G. "The Identification of Molecular Spectra" Chapman & Hall, London, 1941.

Encls: (A) Table I, Table II and Table III.

(B) Plates I through Plate V.

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1. Reference (a) requested the laboratory to develop a burning type pyrotechnic composition which would provide a high level of radiant energy in that region of the spectrum from which all solar radiation is absorbed by the earth's atmosphere above 60,000 feet. In order for a pyrotechnic composition to meet the above requirements, an appreciable portion of the radiant energy emitted from a burning composition should fall in wavelengths of less than 2900 A. Solar radiant energy of less than 2900 A is absorbed at altitudes above 60,000 feet by atmospheric ozone. Another practical limitation is imposed by the atmospheric scattering of radiant energy of wavelengths less than 2700 A. Therefore, the investigation of pyrotechnic compositions which during burning emit radiations in the wavelength region of 2700-2900 A appeared to be the most desirable approach. The transmission in this region under optimum conditions is approximately 40% per mile compared to 60% per mile for visible radiation.

2. The spectra of pyrotechnic flames consist of superimposed line, band and continuous spectra due to atoms, molecules and incandescent particles. Incandescent particles in pyrotechnic flames produce a radiation continuum somewhat similar to that produced by black body radiators. Because the temperatures of pyrotechnic flames rarely exceed 3000 K, the energy obtained from incandescent particles in the 2700-2900 A wavelength region normally will not be more than .001 percent of the total energy. The energy in this region can be increased by excitation of molecular band spectra. The available excitation energies are determined by the flame temperatures and therefore in conventional pyrotechnic flames are limited to a few electron volts. Because of the temperature limitations, the desired band spectra must arise from transitions between a few of the lower levels of the molecules, the lower level being the ground state and the upper level not exceeding a few electron volts.

3. A survey of molecular emission spectra was undertaken to determine possible pyrotechnic formulations which might produce the desired radiations. Reference (b) indicated that if sufficient excitation energy was available in a flame containing boron oxide (BO), phosphorous oxide(PO), silicon oxide (SiO) or sulfur (S_2), band spectra in the desired wavelength region would be produced. Table I of enclosure (A) lists the desired molecular emitters, the band spectra and the excitation energy of each emitter.

4. The formulations of the experimental compositions investigated are shown in Table II of enclosure (A), which also indicates the desired molecular emitter from each pyrotechnic composition. It should be noted that every attempt was made to obtain high flame temperatures with a burning rather than an explosive mixture. For this reason the percentage of magnesium in the sodium nitrate mixtures was kept low. Wax was used as a binder and also as a means of increasing the burning time of the pressed pellets. The graphite facilitated the pressing of the compositions into compact pellets.

5. The radiation from the burning flares was recorded by means of a Bausch and Lomb medium quartz spectrograph. The spectrograms obtained are shown in Plates I through Plate V of enclosure (B). Information regarding each spectrogram is found in Table III of enclosure (A).

6. As discussed in paragraph 2, continua were obtained with line and band spectra superimposed. The continuum shown in plate IV, Figure 1 extends to approximately 2700 A. Self reversal of the 2852 A magnesium line (Plate IV) indicates that excitation energies of at least 4.3 electron volts were produced. Attempts to produce radiation in the 2700-2900 A wavelength region by excitation of molecular band spectra were not successful.

7. It can be concluded that the radiant energy obtainable in the short wavelength regions of the spectrum is appreciably limited by the flame temperature of the burning pyrotechnic compositions. It is felt that it would be useless to investigate additional flare compositions until the high level radiant energy requested by reference (a) is defined. It is believed that a practical definition could be obtained by determining the minimum energy in the desired wavelength region which would meet the tactical requirements of proposed receivers.

8. This report terminates the work which has been undertaken in connection with the project established by reference (a).

L. LoPiego

E. H. Winger

LL/EHW/aao

Table I (Enclosure (A)

Desired Molecular Emitter	Excitation Energy (Electron volts)	Band Spectra (A)
Boron Oxide (BO)	5.29	3493-2203
Phosphorous Oxide (PO)	5.0	2721-2288
Silicon Oxide (SiO)	5.26	2925-2176
Sulfur (S_2)	3.914	6300-2300

Table II (Enclosure (A)

Composition Number	Formulation (% by w.t.)	Desired Emitter
1	$NaNO_3$-60; B-40	BO
2	$NaNO_3$-68.50;Mg-6.85;P-13.4;WAX-6.85; Graphite 4.1%	PO
3	$NaNO_3$-64;Mg-12.8;Si-12.8;WAX-6.5;Graphite 3.9	S_iO
4	$NaNO_3$-70;B-30	BO
5	$NaNO_3$-50;Mg10;CaSi-10;B-22;WAX-5;Graphite 3	SiO and BO
6	$NaNO_3$-50;Mg10;Si-10;B-22;WAX 5; Graphite 3	SiO and BO
7	$NaNO_3$-50;Mg-5;P-10,B-27;WAX-5;Graphite 3	BO and PO
8	$NaNO_3$-60;Mg-18.3;P-12;WAX 6; Graphite 3.7	PO
9	$Ba(NO_3)_2$-51.6;Mg-36.2;CaSi-3.1;Al-2.1;WAX 7	SiO
10	Formula 9-90%;P-10%	PO
11	Formula 9-90%;Si-10%	SiO
12	Formula 9-90%;S-10%	S_2
13	$NaNO_3$-33.3%;$2rNO_3$-33.3%;B-33.3%	BO

Table III (Enclosure (A)

Plate Number (See Enclosure (B)	Figure Number (See Enclosure (B)	Composition Number (See Table II)	Exposure Time (Secs.)
I	1	1	15
I	2	2	15
I	3	3	1
II	1	4	2.5
II	2	5	5
II	3	6	9
III	1	7	2.5
III	2	8	12
IV	1	9	15
IV	2	10	8
IV	3	11	10
V	1	12	10
V	2	13	10

FIGURE 1 FIGURE 2 FIGURE 3

FIGURE 1

FIGURE 2

FIGURE 3

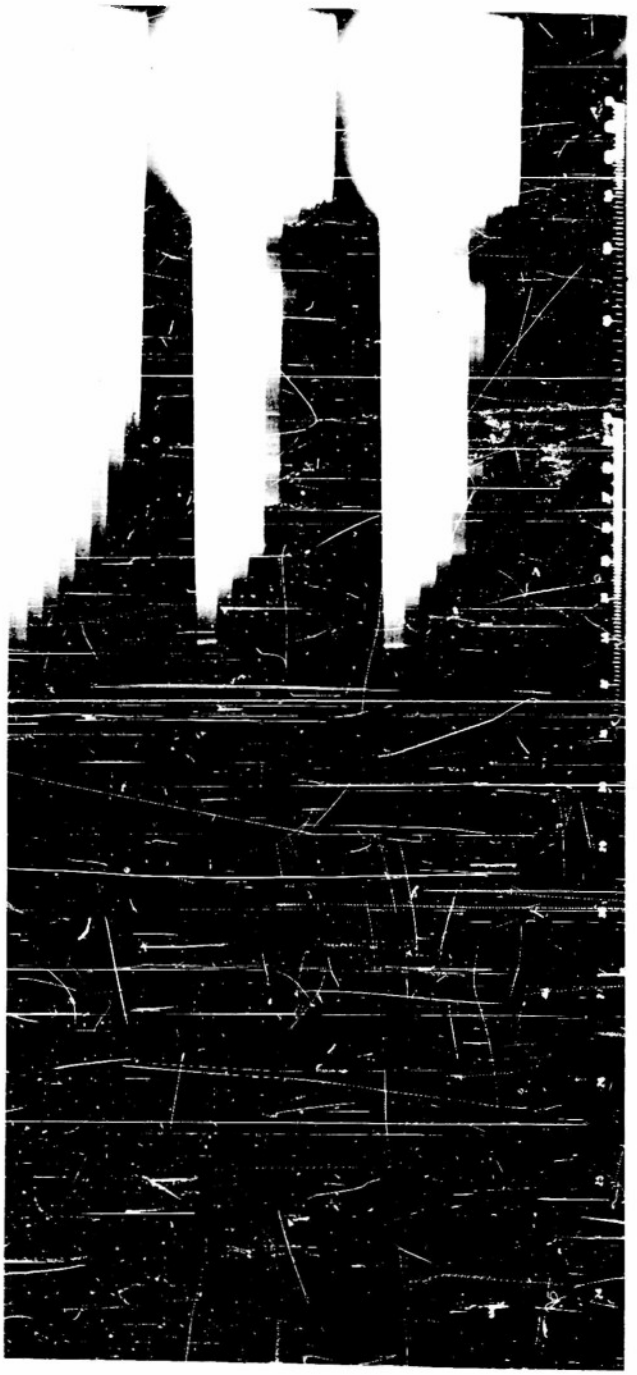

FIGURE 1

FIGURE 2

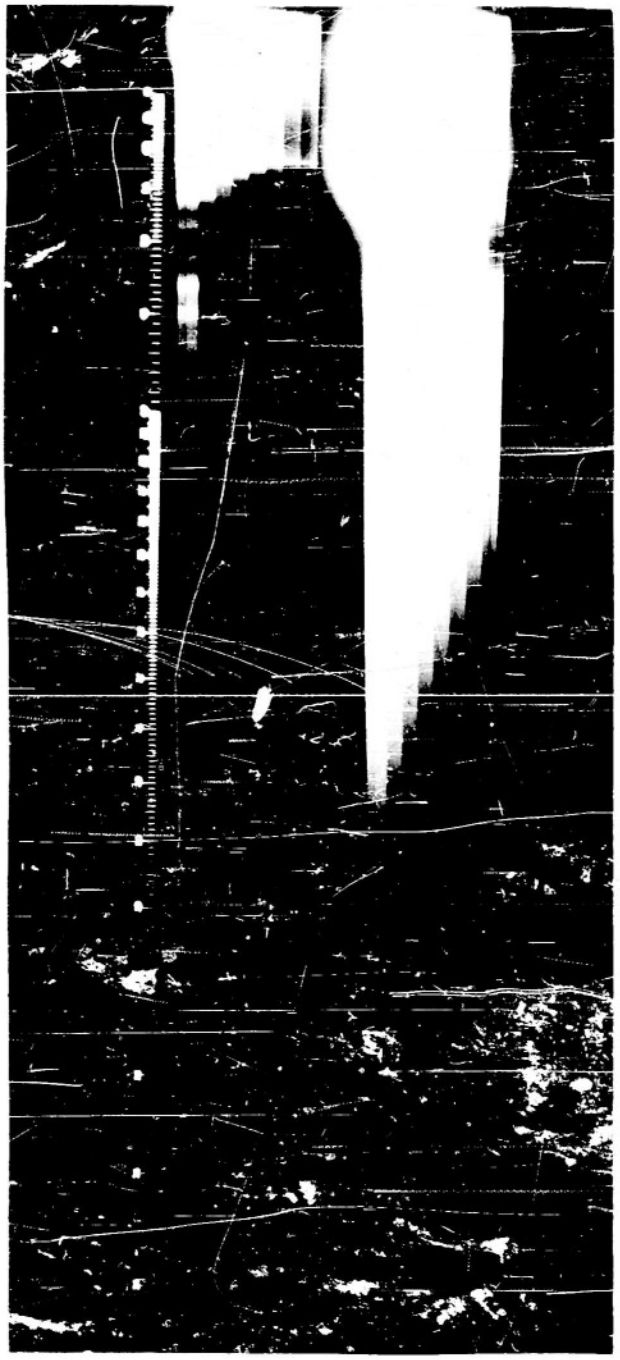

FIGURE 1

FIGURE 2

FIGURE 3

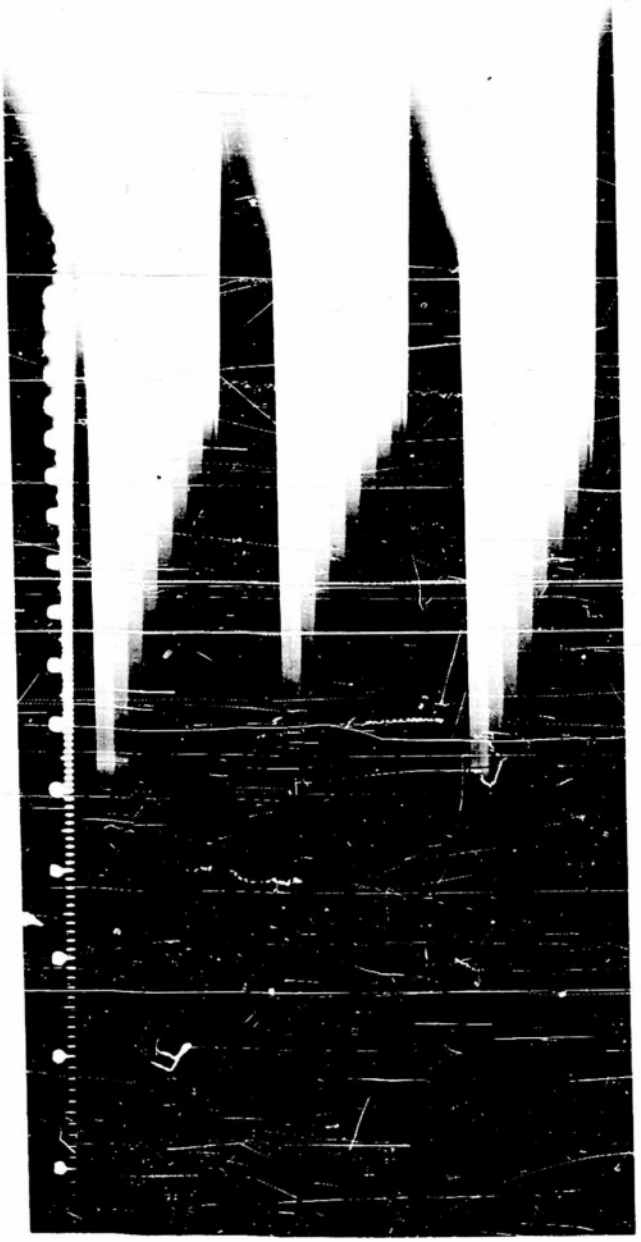

FIGURE 2

FIGURE 1